Separate equipment grounding and grounded conductors are run from the grounded transformer secondary terminal to the panel.

Figure 9–9(B) shows the requirements for grounding if the bonding jumper is placed in the panel. In this situation, there can be no connection between the grounded transformer secondary terminal and the transformer enclosure in the transformer enclosure itself if a metal raceway is used between the transformer enclosure and the panel. Bonding the transformer grounded secondary terminal to the transformer enclosure and bonding the grounded conductor to the equipment ground in the panel would create a parallel path for the flow of unbalanced neutral current between the panel and the transformer enclosure. The unbalanced neutral current would flow from the panel back to the transformer through
the parallel path created by the grounded conductor and the metal raceway system. This would be a violation of Section 250.6(A) of the NEC and could result in unsafe neutral-to-earth voltages in the system.

The transformer enclosure can be grounded by running a separate equipment-grounding conductor from the panel back to the transformer enclosure, as shown in Figure 9–9(B). It is also possible to use a metallic raceway as the grounding conductor between the panel and the transformer enclosure. If the metal raceway is used as the equipment grounding conductor between the panel and transformer enclosure, the raceway and fittings must be listed for the application. This will ensure that a solid connection exists for proper grounding continuity. Note that in the arrangement shown in Figure 9–9(B), there is no possibility for unbalanced neutral current to find a parallel path from the panel back to the transformer secondary.

The size of the bonding jumper is based on the size of the phase conductors of the separately derived system in accordance with Sections 250.30(A)(1) and 250.28(D) of the NEC. Table 250.66 applies if the ungrounded phase conductors of the derived system are smaller than 1100 kcmil copper or 1750 kcmil aluminum. If the ungrounded phase conductors are larger than 1100 kcmil copper or 1750 kcmil aluminum, the bonding jumper must be sized no smaller than 12.5% of the cross-sectional area of the ungrounded phase conductor. The equipment grounding conductor between the transformer enclosure and the panel should be sized in the same manner as the bonding jumper, since it is on the line side of the first disconnect of the separately derived system.

EXAMPLE 9-7

A separately derived system is supplied by a three-phase step-down transformer. The ungrounded secondary conductors of the derived system are 300 kcmil THW copper. Determine the required copper bonding jumper and copper equipment-grounding conductor for this installation.

**Solution:** The size is read directly from Table 250.66 as #2 AWG copper.

The grounding electrode conductor must be connected to the grounding electrode system either at the transformer enclosure, as shown in Figure 9–9(A), or at the first disconnect, as shown in Figure 9–9(B). Section 250.30(A)(2) of the NEC requires connection of the grounding electrode conductor to the system in the same location as the bonding jumper. Section 250.30(A)(4) of the NEC requires that the connection to the grounding electrode system be as near as practicable to the grounding electrode conductor connection to the system. Also, Section 250.30(A)(4) of the NEC requires that, if available, the grounding electrode system of the separately derived system must be comprised of the effectively grounded building structural steel or effectively grounded metal water pipe within 5 feet of the entrance to the building. If structural steel or a metal water pipe is not available, a concrete-encased electrode, ground ring, or made electrode can be used. If the separately derived system originates in service entrance equipment, the grounding electrode system of the service may also be used as the grounding electrode system for the
separately derived system. Sizing of the grounding electrode conductor is based on Table 250-66 for the derived phase conductors.

EXAMPLE 9-8

Determine the required copper grounding-electrode conductor for the separately derived system of Example 9-7.

Solution: In this case, the grounding electrode conductor is based on the 300 kcmil copper ungrounded phase conductors of the separately derived system. The required size is read from Table 250.66 as #2 AWG copper.

The grounding requirements for a separately derived system supplied from an emergency generator are illustrated in Figure 9-10. Recall that a separately grounded system is

![Diagram of grounding systems](image)

**A. Three-Pole Transfer Switch**

**B. Four-Pole Transfer Switch**
one in which there is no direct electrical connection between the ungrounded and grounded conductors of the main supply and the derived system. Figure 9–10(A) shows a generator connected to a transfer switch in which only the ungrounded conductors are switched. The grounded conductor is not switched by the transfer switch. Since this is not considered a separately derived system, connection of the grounded conductor to the grounding electrode system or other grounding conductor is not permitted. In this instance, the grounded conductor is connected to the grounding electrode system only at the service disconnect, as shown. The grounding conductor is run to the generator only to provide for equipment grounding.

In the system shown in Figure 9–10(B), the transfer switch switches both the ungrounded and grounded conductors. By definition, this is considered a separately derived system. As such, bonding of the grounded conductor to the grounding electrode system is required at the generator. Failure to do so will result in the loss of system ground when the transfer switch switches to the generator source.

9–6

EQUIPMENT GROUNDING

Grounding of electrical equipment will ensure that dangerous voltages will not be present on equipment enclosures should a ground fault occur. The grounding of equipment enclosures is accomplished by connecting an equipment grounding conductor to the equipment enclosure. This equipment grounding conductor is then connected to the grounding electrode system at the point of supply. In addition, equipment enclosures are often connected to grounding electrodes placed in the vicinity of the equipment. However, it must be understood that a metallic path is required to complete the return path for the flow of fault current back to the source. A grounding connection that relies solely on an earth return path is a violation of the NEC.

In the event of a ground fault between the ungrounded conductor and ground, fault current will flow from the ungrounded conductor through the equipment grounding conductor and back to the source. Since the grounding conductor is expected to carry fault current, it must be sized large enough to carry the fault current without damage. Figure 9–11 shows the method used to ground the metallic service raceways entering the service equipment enclosure. Since these raceways contain the service entrance conductors, they are considered electrical equipment on the line side of the service overcurrent device. As a result, the equipment bonding jumpers are sized based on Table 250.66 of the Code. As in the case of the sizing of the main bonding jumper, Section 250.102(C) of the NEC requires sizing the equipment bonding jumper at 12.5% of the cross-sectional area of the service entrance conductor for service entrance conductors larger than 1100 kcmil copper or 1750 kcmil aluminum. Also, Section 250.102(C) requires that if aluminum service entrance conductors are used, the copper equipment-bonding jumper is sized based on the equivalent-size copper service entrance conductors. If the equipment bonding jumpers are run in parallel with the service entrance conductors, as shown in Figure 9–11(A), Section 250.102(C) requires each equipment bonding jumper to be sized based on the cross-sectional area of the service conductors in each conduit. A single, unspliced equipment bonding jumper run through the grounding bushings, as shown in Figure 9–11(B), is also
permitted to bond the raceways on the supply side of the service overcurrent device. The size of this single equipment-bonding jumper must be based on the total cross-sectional area of all ungrounded phase conductors.

**EXAMPLE 9-9**

A service consists of four 350 kcmil XHHW copper conductors per phase routed in rigid steel conduit. Determine the required equipment bonding jumpers to bond the raceway to the ground bus in the service equipment enclosure.

**Solution:** For parallel installation of the equipment bonding jumpers, the size is based on the cross-sectional area of the conductors in each conduit. Since the conductors in each conduit are 350 kcmil, the required bonding jumper size is read directly from Table 250.66
as #2 AWG copper. If a single bonding jumper is used, the size is based on the cross-sectional area of all phase conductors, or 1400 kcmil in this case. The 12.5% rule applies since the equivalent cross-sectional area exceeds 1100 kcmil for copper service-entrance conductors. The required cross-sectional area of the bonding jumper is \((12.5\%) \times (1400 \text{ kcmil}) = 175 \text{ kcmil}\). Therefore, a #4/0 AWG copper conductor having a cross-sectional area of 211.6 kcmil is required for this installation.

The arrangement of the equipment bonding jumpers located on the load side of the service overcurrent device is shown in Figure 9–12. If the equipment bonding jumpers are run in parallel with the feeder conductors, as shown in Figure 9–12(A), the size of each equipment bonding jumper is based on the rating of the overcurrent

**FIGURE 9–12**
Grounding of Feeder and Branch Circuit Conduits

- Parallel conductors
- Grounding bushings
- Service equipment main bonding jumper
- Ground bus
- Single conductor runthrough
- Grounding bushings
- Service equipment main bonding jumper
device protecting the feeder conductors. Likewise, a single, unspliced equipment bonding jumper may be used, as shown in Figure 9-12(B). The size of this single equipment-bonding jumper is also based on the rating of the overcurrent device protecting the feeder conductors. The required size is selected from Table 250.122 as required by Section 250.102(D) of the NEC. This table is shown in Table 9-2. Note that the table lists both copper and aluminum or copper-clad aluminum equipment grounding conductors.

<table>
<thead>
<tr>
<th>Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Conduit, etc., Not Exceeding (Amperes)</th>
<th>Size (AWG or kcmil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>Aluminum or Copper-Clad Aluminum*</td>
</tr>
<tr>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td>20</td>
<td>12</td>
</tr>
<tr>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>60</td>
<td>10</td>
</tr>
<tr>
<td>100</td>
<td>8</td>
</tr>
<tr>
<td>200</td>
<td>6</td>
</tr>
<tr>
<td>300</td>
<td>4</td>
</tr>
<tr>
<td>400</td>
<td>3</td>
</tr>
<tr>
<td>500</td>
<td>2</td>
</tr>
<tr>
<td>600</td>
<td>1</td>
</tr>
<tr>
<td>800</td>
<td>1/0</td>
</tr>
<tr>
<td>1000</td>
<td>2/0</td>
</tr>
<tr>
<td>1200</td>
<td>3/0</td>
</tr>
<tr>
<td>1600</td>
<td>4/0</td>
</tr>
<tr>
<td>2000</td>
<td>250</td>
</tr>
<tr>
<td>2500</td>
<td>350</td>
</tr>
<tr>
<td>3000</td>
<td>400</td>
</tr>
<tr>
<td>4000</td>
<td>500</td>
</tr>
<tr>
<td>5000</td>
<td>700</td>
</tr>
<tr>
<td>6000</td>
<td>800</td>
</tr>
</tbody>
</table>

Note: Where necessary to comply with 250.4(A)(3) or 250.4(B)(4), the equipment grounding conductor shall be sized larger than given in this table.

*See installation restrictions in 250.120.

Source: Reprinted with permission from NFPA 70 The National Electric Code © 2002, National Fire Protection Association, Quincy, MA 02269. This reprinted material is not the referenced subject which is represented only by the standard in its entirety.
EXAMPLE 9-10

A 600 A feeder consists of two 350 kcmil THW copper conductors per phase. The feeder is protected by a 600 A breaker in the main service panel. The feeder conductors are arranged in parallel in two raceways. Determine the required copper equipment-bonding jumper.

**Solution:** The size of the bonding jumpers is the same regardless of whether the jumpers are run in parallel or as a single, unspliced conductor. The required size is read from Table 250.122 as #1 AWG copper.

The routing of equipment grounding conductors from the panel to the equipment is shown in Figure 9-13. Note that Figure 9-13(A) pertains to the case where there is a single ungrounded conductor per phase. In this instance, the size of the equipment grounding conductor is determined by the rating or setting of the overcurrent device supplying the ungrounded conductors. For feeders involving parallel conductors, the equipment grounding conductor must be run in each conduit from the panel to the equipment, as shown in Figure 9-13(B). The size of the equipment grounding conductor in each conduit is based on the rating or setting of the overcurrent device protecting the ungrounded feeder conductors.

Although equipment grounding conductors are usually copper, Section 250.118 of the *NEC* permits the use of several other raceway systems as equipment grounding conductors.

---

**FIGURE 9-13**

Equipment Grounding Conductor

A. Single Conductor per Phase

B. Parallel Conductors per Phase
The reader is referred to this NEC section for a list of suitable raceway systems and application requirements.

Where flexible conduit is used to prevent the transmission of vibration from electrical equipment to the raceway system, or where employed to allow for flexibility of connections, a separate equipment grounding conductor must be used. This equipment grounding conductor is generally a copper conductor and must be routed with the circuit conductors. The equipment grounding conductor must be bonded to the equipment enclosures at both ends to ensure continuity of the ground path. Section 250.102(E) of the NEC allows the equipment grounding conductor to be routed on the outside of the flexible conduit provided the grounding conductor is securely fastened to the conduit and does not exceed 6 feet in length. There is no restriction on length if the equipment grounding conductor is run inside the flexible conduit.

In most instances, the equipment grounding conductor size is based on the rating of the overcurrent device protecting the ungrounded circuit conductors. In instances where the size of the ungrounded circuit conductors is increased to compensate for voltage drop, or for other reasons, Section 250.122(B) of the NEC requires the size of the equipment grounding conductor to be increased in proportion to the increase in the cross-sectional area of the ungrounded conductors as well. This requirement is due to the fact that the lower resistance of the larger conductor will result in an increase in the magnitude of the ground fault current. The equipment grounding conductor will be expected to carry this increased fault current. The following example illustrates the calculation.

**EXAMPLE 9-11**

A 200 A feeder would normally consist of one #3/0 AWG THW copper conductor per phase. The feeder would be protected by a 200 A breaker in the originating panel. However, due to voltage drop considerations, the feeder conductor size was increased to 250 kcmil THW copper. The lower resistance of the larger conductor would result in less voltage drop for this feeder. Determine the required copper equipment-bonding jumper.

**Solution:** From Table 250.122, a #6 AWG copper equipment-grounding conductor would be required if the equipment grounding conductor were sized based on the use of a #3/0 AWG copper phase-conductor and a 200 A overcurrent device. This #6 AWG copper conductor has an area of 26,240 cmm. To determine the size of the equipment grounding conductor required for use with the 250 kcmil phase conductors, the cross-sectional area must be increased by the same percent as the phase conductors. The cross-sectional area of the #3/0 AWG copper conductor is 167,800 cmm. The percent increase in circular mil area between the #3/0 AWG and 350 kcmil conductor is

\[
\% \text{ increase} = \frac{250,000 - 167,800}{167,800} \times 100 = 49\%
\]

This increase is now applied to the cross-sectional area of the original #6 AWG copper equipment-grounding conductor to determine the minimum required area of the new grounding conductor:
Required cross-sectional area = 26,240 cmil + (0.49)(26,240 cmil) = 39,098 cmil

Therefore, a copper conductor having a cross-sectional area of at least 39,098 cmil is required. The required equipment grounding conductor is #4 AWG copper having a cross-sectional area of 41,740 cmil.

The use of instantaneous trip circuit breakers or motor circuit protectors to provide overcurrent protection of motor circuits requires special consideration when determining the size of the equipment grounding conductor. As described in Chapter 13, the NEC allows the setting of these overcurrent devices to exceed the ampacity of the motor feeder conductors. In essence, the instantaneous trip breaker or motor circuit protector protects the motor feeder conductors against short circuit fault current levels only. The use of a motor overload element provides the necessary overload protection for the motor. These overload elements are generally sized at 115% to 125% of the full-load current of the motor. When instantaneous trip breakers or motor circuit protectors are used, Section 250.122(D) permits the required equipment grounding conductor to be determined using the rating of the overload element, then referring to Table 250.122. The rating of the motor branch circuit overcurrent device is used as the basis for sizing the equipment grounding conductor if inverse time breakers or time delay fuses are used to protect the motor branch circuit conductors.

Section 250.97 of the NEC specifies requirements for bonding metal raceways and cables containing circuits operating above 250 volts to ground. These methods of bonding will ensure continuity around any concentric or eccentric knockouts encountered. These requirements would apply to branch circuit raceway systems operating at 277 volts to ground supplied from a 480V/277 V system. The reader is referred to the appropriate NEC code section for specific details and application information.

Sections 250.92(B) and 250.94 of the NEC specify the requirements for bonding service raceways, meter troughs, wireways, and other enclosures located on the supply side of the service overcurrent device. These methods of bonding are required to guarantee the integrity of the ground path in the event of a line-to-ground fault involving the service conductors located on the supply side of the main service overcurrent device. The reader is referred to the appropriate NEC code section for specific details and application information.

GROUND FAULT CIRCUIT INTERRUPTION

The basic principle of operation and location requirements for ground fault protection of receptacles were discussed in Chapter 5. In addition to the requirements for receptacles, the NEC requires the use of ground fault protection on services and feeders under certain conditions. Specifically, Sections 230.95 and 215.10 of the NEC require ground fault protection on disconnecting devices rated at 1000 A or more on solidly grounded wye systems of greater than 150 V to ground but not exceeding 600 V phase to phase. Bear in mind that GFCI detectors are not required on all feeders if GFCI protection is provided by an
upstream device. For example, a 1000 A feeder disconnect is not required to have a GFCI detection scheme if the upstream service disconnect is provided with GFCI detection. Section 230.95 of the NEC specifies that the rating of the disconnect is the maximum fuse rating capable of being installed in the disconnecting switch. For circuit breakers, the rating is considered to be the maximum possible setting of the adjustable trip circuit breaker.

Two configurations for the detection of ground faults are possible, as shown in Figure 9–14. Figure 9–14(A) shows the window-type detector in which all ungrounded conductors (phase) and the grounded conductor (neutral) pass through the detector window. Under normal operating conditions, the load current will flow toward the load in the phase conductors, with the unbalanced neutral current returning through the ungrounded conductor. The vector sum of the phase and neutral currents will equal zero under normal conditions. If a ground fault occurs between an ungrounded conductor and the grounded metal raceway, as shown in Figure 9–14(A), the ground fault current, $I_G$, will flow as shown. This ground fault current will return to the source by means of the raceway and
equipment bonding jumper without passing through the window detector. This creates an unbalance of current through the window, causing the ground fault detector to operate and trip the breaker. This type of window sensor is used on either service or feeder disconnects.

The configuration shown in Figure 9-14(B) utilizes a current transformer that detects the current passing between the grounding terminal and the neutral terminal in the panelboard. Note again that under normal operating conditions, there is no current flowing in this connection. If, however, a phase-to-ground fault occurs, as shown, current will return to the grounding terminal by means of the equipment grounding conductor. The fault current flows from the grounding terminal to the neutral terminal and back to the source by means of the grounded circuit conductor. The ground fault sensor detects the ground fault and causes the disconnecting device to open. This type of detector can only be used where it is permitted to connect the grounded conductor to the grounding conductor.

Section 230.95(A) of the NEC specifies that the trip setting of the ground fault sensor cannot exceed 1200 A. In addition, the time delay cannot exceed 1 second for ground fault currents of 3000 A or more. Operation of the ground fault detector must result in the opening of all ungrounded conductors in the system on the load side of the disconnecting device. It is also important to note that the ground fault detection schemes just described will detect ground faults only on the load side of the GFCI sensing device. Also, the GFCI detector will not detect overloads or phase-to-phase faults not involving ground.

9-8 GROUNDING OF INSTRUMENT TRANSFORMERS

In many commercial and industrial applications, instrument transformers are used to transform the high load currents and voltages to smaller levels that can be applied to various metering and protective devices. The most common use of instrument transformers is as current transformers applied to large ampacity services. In addition, voltage transformers are commonly used to step down the voltage of services rated above 600 V. All medium voltage installations use voltage and current transformers to provide the appropriate levels to the metering elements and protective relays.

Instrument transformer secondaries must be grounded to prevent dangerous overvoltages from occurring on the secondary system. Section 250.170 of the NEC requires that the secondary circuits of instrument transformers operating on systems where the primary voltage is 300 V or more to ground must be grounded. Also, Sections 250.174(A) and 250.174(B) require the cases of instrument transformers not mounted on switchboards, or mounted on switchboards not having any live parts exposed, must be grounded in most locations. Section 250.174(C) specifies that cases of instrument transformers mounted on live front switchboards must not be grounded.

Figure 9-15(A) shows the proper location of the secondary ground connection for a current transformer. Grounding of a voltage or potential transformer secondary is shown in Figure 9-15(B). In each figure, only one instrument transformer is shown for the purpose of clarity. Instrument transformers connected to other ungrounded conductors must be similarly grounded. Section 250.178 of the NEC also requires that the minimum-size grounding conductor shall be #12 copper or #10 aluminum.